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A method for estimating rock mass strength and elastic modulus of a geothermal reservoir using borehole data: Soultz-sous-Forêts case study

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ABSTRACT

Knowledge of the strength and elastic modulus of a reservoir rock is important for the optimisation of a particular geothermal resource. The reservoir rock for many geothermal projects in the Upper Rhine Graben (URG), such as those at Soultz-sous-Forêts and Rittershoffen (both France), is porphyritic granite.

High fracture densities (up to ~30 fractures/m) in this reservoir rock require that we consider the strength and elastic modulus of the rock mass, rather than the intact rock. Here we use uniaxial deformation experiments performed on intact rock coupled with Geological Strength Index (GSI) assessments—using the wealth of information from core and borehole analyses—to provide rock mass strength and elastic modulus estimates for the granite reservoir at Soultz-sous-Forêts (from a depth of 1400 to 2200 m) using the generalised Hoek-Brown failure criterion.

The average uniaxial compressive strength and elastic modulus of the intact granite is 135 MPa (this study) and 55-70 GPa (data from the literature), respectively. The modelled strength of the intact granite is 360 MPa at a depth of 1400 m and increases to 455 MPa at 2200 m (using a reasonable estimate for the empirical mi term of 40). Strength of the rock mass varies in accordance with the fracture density the extent and nature of the fracture infill, reaching lows of ~40 MPa (in, for example, the densely fractured zones at depths of ~1640 and ~2160 m, respectively) and highs of above 300 MPa (in, for example, the largely unfractured zone at a depth of ~1940-2040 m). Variations in rock mass elastic modulus are qualitatively similar (values vary from a couple of GPa up to ~65 GPa).

Our study highlights a simple and cost-effective method to assess the in-situ strength and elastic modulus of reservoir rock masses, important for a wide range of modelling and stimulation strategies. We recommend that this method be used to characterise geothermal reservoirs worldwide.